ELECTRICAL CONNECTION PROTECTOR KIT AND METHOD FOR USING THE SAME

Related Applications

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~~This is a continuation-in-part application of pending United States Patent Application Serial Number 09/539,541, filed March 31, 2000, the disclosure of which is incorporated herein by reference in its entirety.~~

Field of the Invention

The present invention relates to electrical connectors and, more particularly, to means for protecting electrical connections.

Background of the Invention

"V"-type electrical connections or splices (also referred to as "stub" or "pigtail"-type connections) are often employed for motor connections. Such electrical connections may be exposed to dust, moisture and/or other corrosives. The electrical connections may also be subjected to mechanical impacts and/or vibration. It is, therefore, desirable to protect the connection from the surrounding environment.

One method of protecting an electrical motor connection includes applying a gummy adhesive tape around the connection. Another method includes placing a plastic cap over the connection and securing the cap in place by wrapping an adhesive tape around the cap and connection cables. Yet another method includes placing a plastic cap over the connection and securing the cap in place by inserting a pin through the cap (which may be provided with preformed holes) and between the cables. In each of the latter two methods, a relatively thin layer of grease may be used to facilitate pushing the cap over the connection. It is also known to apply mastic to a connection and wrap or heat shrink a cover over the connection and mastic.

While the foregoing methods provide some protection for V-type electrical connections, improved and more convenient protection is needed.

Summary of the Invention

According to embodiments of the present invention, a connection protector kit for use with an electrical stub connection includes a flexible cap having first and second opposed ends and an interior wall defining a cavity. The first end is closed and an opening is formed in the second end and in communication with the cavity. A gel is disposed in the cavity. The cavity and the gel are adapted to receive the stub connection.

The kit may include means for retaining the cap on the connection. More particularly, the retaining means may be operative to maintain the cap in a compressed position. The cap may include a plurality of expandable corrugations.

The means for retaining may include a pin and a pair of opposed holes may be formed in the cap and adapted to receive the pin therethrough. The cap may be formed of a frangible thermoplastic elastomer. The pin may be connected to the cap by an integrally molded bridge member.

The means for retaining may include a clamp. Preferably, the clamp includes at least one inwardly extending locating projection. Preferably, the cap includes an inwardly extending channel adapted to receive the inwardly extending locating projection.

Preferably, the cap is formed of a material having a flexural modulus of between about 5,000 and 100,000 psi and a durometer of between about 40 Shore A and 90 Shore D. Preferably, the gel has a Voland hardness of between about 5 and 30 grams force, an elongation of at least 100%, a stress relaxation of no more than 50%, and a tack of greater than about 6 grams.

According to further embodiments of the present invention, a protected electrical connection assembly includes a flexible cap defining an opening and having an interior wall defining a cavity. The cavity communicates with the opening. A stub connection of the assembly includes a pair of elongated, electrically conductive elements joined at respective terminal ends thereof. The conductive elements define a crotch therebetween and extend through the opening. The terminal ends, and at least a portion of each of the conductive elements, are disposed in the cavity of the cap. A gel is disposed in the cavity and is interposed between the stub connection and the

interior wall of the cap. Retaining means are operative to retain the cap on the connection.

Preferably, the gel is elongated and elastically deformed and applies an outward force against the connection and the interior wall. Preferably, at least a portion of the gel is elongated at least 50%. Preferably, the cap is compressed. The cap may be maintained in compression by the retaining means.

According to further embodiments of the present invention, a connection protector kit for use with an electrical stub connection includes a flexible cap having first and second opposed ends and an interior wall defining a cavity. The first end is closed and an opening is formed in the second end and in communication with the cavity. A clamp is provided to retain the cap on the connection. The cavity is adapted to receive the stub connection.

According to further embodiments of the present invention, a method for protecting an electrical stub connection includes placing a cap and a gel over the stub connection such that the stub connection is received in a cavity of the cap and the gel is interposed between the stub connection and an interior wall of the cap. The gel is deformed and elongated about the stub connection. The gel is maintained in the elongated state such that the gel exerts an outward force on the stub connection and the interior wall of the cap.

The step of deforming and elongating the gel may include placing the gel in the cavity and thereafter inserting the stub connection into the gel such that the gel is displaced by the stub connection and thereby elongated. The step of deforming and elongating the gel may include placing the gel in the cavity and thereafter compressing the cap such that the gel is displaced and thereby elongated. Preferably, the step of deforming and elongating the gel includes elongating at least a portion of the gel by at least 50%.

The method may include inserting a pin through the cap and a crotch of the stub connection. The method may include securing a clamp about the cap. The cap may be expanded to accommodate the stub connection. More particularly, the cap may be expanded by expanding corrugations in the cap.

According to embodiments of the present invention, a method for protecting an electrical stub connection includes providing a cap having a cavity and a gel disposed in the cavity. The stub connection is inserted into the cavity and the gel such that the stub connection displaces and thereby deforms and elongates the gel. The cap

is compressed to further displace and thereby deform and elongate the gel. A pin is inserted through the cap and a crotch of the stub connection to retain the cap on the stub connection and to maintain the gel in the elongated state such that the gel exerts an outward force on the stub connection and the interior wall of the cap.

According to method embodiments of the present invention, a method for protecting an electrical stub connection includes providing a cap having a cavity and a gel disposed in the cavity; inserting the stub connection into the cavity and the gel such that the stub connection displaces and thereby deforms and elongates the gel; compressing the cap to further displace and thereby deform and elongate the gel; and securing a clamp about the cap to retain the cap on the stub connection and to maintain the gel in the elongated state such that the gel exerts and outward force on each of the stub connection and the interior wall of the cap. Preferably, the step of securing a clamp includes inserting a locating projection of the clamp into a crotch of the stub connection.

Objects of the present invention will be appreciated by those of ordinary skill in the art from a reading of the Figures and the detailed description of the preferred embodiments which follow, such description being merely illustrative of the present invention.

Brief Description of the Drawings

Figure 1 is an exploded, perspective view of a protected electrical connection assembly according to embodiments of the present invention;

Figure 2 is a perspective view of the connection assembly of **Figure 1**;

Figure 3 is a cross-sectional view of the connection assembly of **Figure 1** taken along the line **3-3** of **Figure 2**;

Figure 4 is a rear perspective view of a cap forming a part of the connection assembly of **Figure 1**;

Figure 5 is a front perspective view of the cap of **Figure 4**;

Figure 6 is a perspective view of a protected electrical connection assembly according to further embodiments of the present invention;

Figure 7 is a front perspective view of a cap forming a part of the connection assembly of **Figure 6**;

Figure 8 is a rear perspective view of the cap of **Figure 7**;

Figure 9 is a perspective view of a protected electrical connection assembly according to further embodiments of the present invention;

Figure 10 is a side elevational view of the connection assembly of **Figure 9**;

Figure 11 is a perspective view of a cap/pin assembly according to further embodiments of the present invention;

Figure 12 is a perspective view of a protected electrical connection assembly according to further embodiments of the present invention;

Figure 13 is a perspective view of a clamp forming a part of the connection assembly of **Figure 12**;

Figure 14 is a further perspective view of the clamp of **Figure 13**;

Figure 15 is a side elevational view of the clamp of **Figure 13**;

Figure 16 is an end view of the clamp and a cap forming a part of the connection assembly of **Figure 12**;

Figure 17 is a cross-sectional view of the connection assembly of **Figure 12** taken along the line **17-17** of **Figure 12**;

Figure 18 is a perspective view of a clamp according to further embodiments of the present invention;

Figure 19 is a perspective view of the clamp of **Figure 18** in a fully open position;

Figure 20 is a side elevational view of the clamp of **Figure 18** in the fully open position;

Figure 21 is a perspective view of a protected electrical connection assembly according to further embodiments of the present invention;

Figure 22 is a perspective view of a clamp forming a part of the connection assembly of **Figure 21**;

Figure 23 is a perspective view of a clamp according to further embodiments of the present invention;

Figure 24 is a side elevational view of the clamp of **Figure 23**;

Figure 25 is an end view of a clamp and a cap forming a part of a protected electrical connection assembly according to further embodiments of the present invention; and

Figure 26 is a perspective view of the clamp of **Figure 25**.

Detailed Description of the Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

With reference to **Figures 1-3**, an electrical connection kit according to embodiments of the present invention is shown therein and generally designated **100**. The kit **100** includes a mass of gel **110**, a cap **130** and a pin **120**. The kit **100** may be mounted on a V-shaped stub connection **10** to provide a protected electrical connection assembly **101** (see **Figures 2** and **3**). As will be appreciated from the description that follows, in various embodiments the kit **100** may be quickly installed and cold-applied (i.e., installed without requiring heating). The kit **100** may provide a reliable and consistent seal to protect the connection **10** from moisture, dirt, dust, corrosives and other harmful environmental substances. The kit **100** may provide such protection even when the connection assembly **101** is submerged in water or other fluid. Moreover, the kit **100** may serve to dampen vibration to reduce or eliminate any tendency for such vibration to loosen the connection **10**. The kit **100** may also electrically and thermally insulate the connection **10** and provide fire retardance.

Turning to the kit **100** in more detail and with reference to **Figures 1-5**, the cap **130** is preferably formed of a molded polymeric material. More preferably, the cap **130** is formed of an elastomer, and most preferably of a thermoplastic elastomer. Suitable materials include SANTOPRENE, a polypropylene/rubber blend, neoprene, silicone or EPDM. However, polyurethane is preferred. Preferably, the cap **130** is formed of a flame retardant material. For example, the polymeric material of the cap **130** may include a suitable additive to make the cap **130** flame retardant. Preferably, the cap material has a durometer of between about 40 Shore A and 90 Shore D, more preferably of between about 70 Shore A and 60 Shore D, and, most preferably, of between about 30 and 50 Shore D. Preferably, the cap has a flexural modulus of between about 5,000 and 100,000 psi, and more preferably of between about 20,000 and 30,000 psi.

For the purposes of discussion, the cap **130** has an axis **A-A** (see **Figure 3**). The cap **130** has an interior surface **132**, an open end **133** and an opposing closed end **134**.

An opening **136** defined in the open end **132** communicates with a cavity **140** defined within the cap **130** by the interior surface **132**. Opposed projections **142** extend radially outwardly from the cap and define longitudinally extending interior channels therein. Holes **144** are pre-formed in each of the projections **142**. Alternatively, the holes may be punched in the cap after the cap is molded. The projections **142** may be omitted and preferably are omitted where the holes are punched after molding. The holes **144** define a transverse axis extending through each of the holes **144**. Generally V-shaped, longitudinally extending grooves **146** are formed in the outer surface of the cap **130** and communicate with the open end edge of the cap **130**. Preferably, and as illustrated, the cap is free of openings other than the opening **136** and the holes **144**.

The pin **120** is preferably formed of a rigid engineering plastic such as nylon or polypropylene. Preferably, the pin **120** is molded. The pin **120** includes a shaft **122** having a flat head **124** on one end and a tapered head **128** on an opposing end. A series of flexible, opposed barbs **126** extend radially outwardly from the shaft **122** between the heads **124**, **128**. The heads **124**, **128** are sized relative to the holes **144** such that the head **128** may be forced through each hole **144**, but thereafter the head **124** and the barbs **126** will each resist removal of the pin through either hole **144**.

The term "gel" has been used in the prior art to cover a vast array of materials from greases to thixotropic compositions to fluid-extended polymeric systems. As used herein, "gel" refers to the category of materials which are solids extended by a fluid extender. The gel may be a substantially dilute system that exhibits no steady state flow. As discussed in Ferry, "Viscoelastic Properties of Polymers," 3rd ed. P. 529 (J. Wiley & Sons, New York 1980), a polymer gel may be a cross-linked solution whether linked by chemical bonds or crystallites or some other kind of junction. The absence of the steady state flow may be considered to be the key definition of the solid like properties while the substantial dilution may be necessary to give the relatively low modulus of gels. The solid nature may be achieved by a continuous network structure formed in the material generally through crosslinking the polymer chains through some kind of junction or the creation of domains of associated substituents of various branch chains of the polymer. The crosslinking can be either physical or chemical as long as the crosslink sites may be sustained at the use conditions of the gel.

Preferred gels for use in this invention are silicone (organopolysiloxane) gels, such as the fluid-extended systems taught in U.S. Pat. No. 4,634,207 to Debbaut

(hereinafter "Debbaut '207"); U.S. Pat. No. 4,680,233 to Camin et al.; U.S. Pat. No. 4,777,063 to Dubrow et al.; and U.S. Pat No. 5,079,300 to Dubrow et al. (hereinafter "Dubrow '300"). These fluid-extended silicone gels may be created with nonreactive fluid extenders as in the previously recited patents or with an excess of a reactive liquid, e.g., a vinyl-rich silicone fluid, such that it acts like an extender, as exemplified by the Sylgard® 527 product commercially available from Dow-Corning of Midland, Michigan or as disclosed in U.S. Pat. No. 3,020,260 to Nelson. Because curing is involved in the preparation of these gels, they are sometimes referred to as thermosetting gels. An especially preferred gel is a silicone gel produced from a mixture of divinyl terminated polydimethylsiloxane, tetraks(dimethylsiloxy)silane, a platinum divinyltetramethyldisiloxane complex, commercially available from United Chemical Technologies, Inc. of Bristol, Pennsylvania, polydimethylsiloxane, and 1,3,5,7-tetravinyltetra-methylcyclotetrasiloxane (reaction inhibitor for providing adequate pot life).

Other types of gels may be used, for example, polyurethane gels as taught in the aforementioned Debbaut '261 and U.S. Pat. No. 5,140,476 Debbaut (hereinafter "Debbaut '476") and gels based on styrene-ethylene butylenestyrene (SEBS) or styrene-ethylene propylene-styrene (SEPSS) extended with an extender oil of naphthenic or nonaromatic or low aramatic content hydrocarbon oil, as described in U.S. Pat. No. 4,369,284 to Chen; U.S. Pat. No. 4,716,183 to Gamarra et al.; and U.S. Pat. No. 4,942,270 to Gamarra. The SEBS and SEPS gels comprise glassy styrenic microphases interconnected by a fluid-extended elastomeric phase. The microphase-separated styrenic domains serve as the junction points in the systems. The SEBS and SEPS gels are examples of thermoplastic systems.

Another class of gels which may be considered are EPDM rubber based gels, as described in U.S. Pat. No. 5,177,143 to Chang et al. However, these gels tend to continue to cure over time and thus may become unacceptably hard with aging.

Yet another class of gels which may be suitable are based on anhydride-containing polymers, as disclosed in WO 96/23007. These gels reportedly have good thermal resistance.

The gel may include a variety of additives, including stabilizers and antioxidants such as hindered phenols (e.g., Irganox™ 1076, commercially available from Ciba-Geigy Corp. of Tarrytown, New York), phosphites (e.g., Irgafos™ 168, ,

commercially available from Ciba-Geigy Corp. of Tarrytown, New York), metal deactivators (e.g., Irganox™ D1024 from Ciba-Geigy Corp. of Tarrytown, New York), and sulfides (e.g., Cyanox LTDP, commercially available from American Cyanamid Co. of Wayne, New Jersey), light stabilizers (i.e., Cyasorb UV-531, commercially available from American Cyanamid Co. of Wayne, New Jersey), and flame retardants such as halogenated paraffins (e.g., Bromoklor 50, commercially available from Ferro Corp. of Hammond, Indiana) and/or phosphorous containing organic compounds (e.g., Fyrol PCF and Phosflex 390, both commercially available from Akzo Nobel Chemicals Inc. of Dobbs Ferry, New York) and acid scavengers (e.g., DHT-4A, commercially available from Kyowa Chemical Industry Co. Ltd through Mitsui & Co. of Cleveland, Ohio, and hydrotalcite). Other suitable additives include colorants, biocides, tackfiers and the like described in "Additives for Plastics, Edition 1" published by D.A.T.A., Inc. and The International Plastics Selector, Inc., San Diego, Calif.

The hardness, stress relaxation, and tack may be measured using a Texture Technologies Texture Analyzer TA-XT2 commercially available from Texture Technologies Corp. of Scarsdale, New York, or like machines, having a five kilogram load cell to measure force, a 5 gram trigger, and ¼ inch (6.35 mm) stainless steel ball probe as described in Dubrow '300, the disclosure of which is incorporated herein by reference in its entirety. For example, for measuring the hardness of a gel a 60mL glass vial with about 20 grams of gel, or alternately a stack of nine 2 inch x 2 inch x 1/8" thick slabs of gel, is placed in the Texture Technologies Texture Analyzer and the probe is forced into the gel at the speed of 0.2 mm per sec to a penetration distance of 4.0 mm. The hardness of the gel is the force in grams, as recorded by a computer, required to force the probe at that speed to penetrate or deform the surface of the gel specified for 4.0 mm. Higher numbers signify harder gels. The data from the Texture Analyzer TA-XT2 may be analyzed on an IBM PC or like computer, running Microsystems Ltd, XT.RA Dimension Version 2.3 software.

The tack and stress relaxation are read from the stress curve generated when the XT.RA Dimension version 2.3 software automatically traces the force versus time curve experienced by the load cell when the penetration speed is 2.0 mm/second and the probe is forced into the gel a penetration distance of about 4.0 mm. The probe is held at 4.0 mm penetration for 1 minute and withdrawn at a speed of 2.00 mm/second. The stress relaxation is the ratio of the initial force (F_i) resisting the probe at the pre-

set penetration depth minus the force resisting the probe (F_f) after 1 min divided by the initial force F_i, expressed as a percentage. That is, percent stress relaxation is equal to

$$\frac{(F_i - F_f)}{F_i} \times 100\%$$

where F_i and F_f are in grams. In other words the stress relaxation is the ratio of the initial force minus the force after 1 minute over the initial force. It may be considered to be a measure of the ability of the gel to relax any induced compression placed on the gel. The tack may be considered to be the amount of force in grams resistance on the probe as it is pulled out of the gel when the probe is withdrawn at a speed of 2.0 mm/second from the preset penetration depth.

An alternative way to characterize the gels is by cone penetration parameters according to ASTM D-217 as proposed in Debbaut '261; Debbaut '207; Debbaut '746; and U.S. Pat. No. 5,357,057 to Debbaut et al., each of which is incorporated herein by reference in its entirety. Cone penetration ("CP") values may range from about 70 (10^{-1} mm) to about 400 (10^{-1} mm). Harder gels may generally have CP values from about 70 (10^{-1} mm) to about 120 (10^{-1} mm). Softer gels may generally have CP values from about 200 (10^{-1} mm) to about 400 (10^{-1} mm), with particularly preferred range of from about 250 (10^{-1} mm) to about 375 (10^{-1} mm). For a particular materials system, a relationship between CP and Voland gram hardness can be developed as proposed in U.S. Pat. No. 4,852,646 to Dittmer et al.

Preferably, the gel **110** has a Voland hardness, as measured by a texture analyzer, of between about 5 and 100 grams force, more preferably of between about 5 and 30 grams force, and, most preferably, of between about 10 and 20 grams force. Preferably, the gel **110** has an elongation, as measured by ASTM D-638, of at least 55%, more preferably of at least 100%, and most preferably of at least 1,000%. Preferably, the gel **110** has a stress relaxation of less than 80%, more preferably of less than 50%, and most preferably of less than 35%. The gel has a tack preferably greater than about 1 gram, more preferably greater than about 6 grams, and most preferably between about 10 and 50 grams. Suitable gel materials include POWERGEL sealant gel available from Tyco Electronics Energy Division of Fuqua-Varina, NC under the RAYCHEM brand.

The connection **10** is illustrative of a connection with which the kit **100** may be employed. However, the kit **100** may be used with stub-type connections of other types such as, for example, a crimped stub connection, a mechanical stub connection, or a twisted stub connection. As used herein, "stub connection" means any connection wherein two or more wires or cables are joined at or near their ends to form a generally V-shaped connection.

The connection **10** is illustrative of, for example, a conventional motor connection. The connection **10** as illustrated includes two cables **12, 16**. The cables **12, 16** may be replaced with any suitable elongated, electrically conductive elements. Each cable **12, 16** has an elongated electrical conductor **12A, 16A** and a surrounding insulator **12C, 16C** (see **Figure 3**). The cables **12, 16** have respective lugs or connectors **20, 22** secured to their terminal ends. A bolt **24** extends through holes **20A** and **22A** in the connectors **20, 22** and is secured in place by a cooperating nut **26**. The cables **12, 16** define a generally V-shaped crotch **14** therebetween. There may be one or more additional cables secured with the ends of the cables **12, 16**, and these additional cables may form further V-shaped crotches with the cable **12**, the cable **16** and/or with one another.

With reference to **Figures 1-3**, the kit **100** may be installed on the connection **10** in the following manner. The gel **110** is placed in the cavity **140** of the cap **130**. Preferably, the gel is placed fully in the rear of the cavity such that there are substantially no voids in the cavity **140** between the closed end **134** and the surface of the gel adjacent the open end **133**. Preferably, the gel **110** is pre-installed (and cured in situ) in the cap **130** so that the user need not place the gel in the cap.

Thereafter, the connection **10** is pushed into the cavity **140** at least until the axis extending through the holes **144** extends through the crotch **14** of the connection **10**. Preferably, the connection is pushed into the cavity **140** until it bottoms out in the cap's closed end **134**. As the connection **10** is inserted, the connection **10** and the interior surface **132** of the cap **130** apply a compressive force to the gel **110**. As a result, the gel **110** elongates and is generally deformed to substantially conform to the outer surfaces of the connection **10** and to the interior surface **132**. The gel may further elongate such that a portion thereof is displaced toward the cap opening. Some shearing of the gel **110** may occur as well. A portion of the gel **110** may be displaced out of the cap **130**. Preferably, at least some of the gel deformation is elastic.

Once the connection **10** is positioned in the cavity as described above, the pin **120** is inserted (tapered end **128** first) through the holes **144** and the crotch **14**. The pin **120** is inserted such that one or more of the sets of barbs **126** pass through the far side hole **144**. Preferably, the pin is inserted sufficiently far that the cap **130** is partially compressed or collapsed. The grooves **146** may facilitate preferential deformation of the cap **130**. In this manner, the user may selectively reduce the volume of the cavity **140** and thereby place the gel **110** under further compressive force. Preferably, this additional compressive force further elongates and elastically deforms the gel **110**. The restoring force in the gel **110** resulting from the elastic deformation causes the gel to operate as a spring exerting an outward force between the cap **130** and the connection **10**. However, the pin **120** preferably abuts the crotch **14** of the connection **10** and may thereby prevent the gel **110** from relatively displacing the cap **130** and the connection **10**. The pin **120** may also maintain the cap in compression as shown in **Figure 2**.

With reference to **Figure 3**, the volumes, shapes and sizes of the gel **110**, the cap **130** and the connection **10** are preferably selected and the kit is preferably installed such that the substantial entirety of the exposed electrically conductive portions (i.e., the connectors **20**, **22**, the exposed portions of the bolt **24**, the nut **26** and the uninsulated portions **12B**, **16B** of the cables **12**, **16**) of the connection **10** are substantially fully immersed in the gel **110**. Preferably, at least the portions **12D**, **16D** of the cable insulations **12C**, **16C** immediately adjacent the exposed conductor portions **12B**, **16B** are substantially completely surrounded by the gel **110**. Preferably, the insulator portions **12D**, **16D** each have a length of at least 0.100 inch. Preferably, when the kit **100** is installed, the gel **110** has a minimum elongation at the interface between the gel **110** and the exposed electrically conductive surfaces of the connection **10** of at least 50%.

Various properties of the gel **110** as described above may ensure that the gel **110** maintains a reliable and long lasting hermetic seal between the cap **130** and the connection **10**. The elastic memory of and the retained or restoring force in the elongated, elastically deformed gel **110** generally cause the gel to bear against the mating surfaces of the connection **10** and the interior surface **132** of the cap **130**. Also, the tack of the gel may provide adhesion between the gel and these surfaces. The gel, even though it is cold-applied, is generally able to flow about the connection **10** and the cap **130** to accommodate their irregular geometries.

Preferably, the gel **110** is a self-healing or self-amalgumating gel. This characteristic, combined with the aforementioned compressive force between the connection **10** and the cap **130**, may allow the gel **110** to re-form into a continuous body if the gel **110** is sheared by the insertion of the connection **10** into the cap **130**. The gel may also re-form if the connection **10** is withdrawn from the gel **110**.

The kit **100** may provide a number of advantages over many prior art methods for protecting a stub-type electrical connection. The kit **100** may be effectively cold-applied. In its preferred supplied configuration, the kit **100** may be installed by simply inserting the connection **10** into the cap **130**, holding the cap **130** in place, and then inserting the pin **120**. Hence, the kit **100** may be quickly and consistently installed without requiring special tools, heat or inordinate strength or dexterity, and without mess. The elastic, displaceable gel **110** and the barbs **126** on the pin **120** allow a kit **100** including a cap **130** of a given size to effectively accommodate connections **10** of a range of different sizes and including more or fewer cables **12, 16**.

The gel **110** may provide a reliable moisture barrier for the connection **10**, even when the assembly **101** is submerged or subjected to extreme temperatures and temperature changes. Preferably, the cap **130** is made from an abrasion resistant material that resists being punctured by the abrasive forces between the motor box and the connection **10**.

The gel **110** may also serve to reduce or prevent fire. The gel is typically a more efficient thermal conductor than air and, thereby, may conduct more heat from the connection. In this manner, the gel **110** may reduce the tendency for overheating of the connection **10** that might otherwise tend to deteriorate the cable insulation and cause thermal runaway and ensuing electrical arcing at the connection **10**. Moreover, in its preferred form, the gel **110** is flame retardant.

With reference to **Figure 6**, an electrical connection protector kit **200** according to further embodiments of the present invention and a protected electrical connection assembly **201** including the kit **200** mounted on the connection **10** are shown therein. The kit **200** generally corresponds to the kit **100** except that the cap **230** of the kit **200** is differently formed from the cap **120**.

The cap **230** is preferably formed in the same manner and of the same materials as the cap **130** except as follows. As best seen in **Figures 7** and **8**, the cap **230** includes a plurality of radially outwardly extending corrugations **250** and a plurality of radially inwardly extending corrugations **252** alternating with the corrugations **250** to present a

zig-zagged cross-section. Preferably, each of the corrugations **250**, **252** extends longitudinally from the open end **233** to the closed end **234** as illustrated. Projections **242** and holes **244** are provided adjacent the open end **233**.

The kit **200** may be used in a similar manner as the kit **100**. The modulus of elasticity of the cap material, the configuration of the cap **230** and the stress relaxation of the gel **210** are preferably relatively selected such that, upon application of a force to the gel **210** (e.g., by inserting the connection **10**) up to a prescribed force, substantially all of the force will be accommodated by elongation and elastic deformation of the gel **210**. Upon application of additional force to the gel **210** (e.g., by further inserting the connection **10** and/or compressing the cap **230** with the pin **220**), the cap **230** will also flex and, upon application of sufficient additional force, the cap material will stretch.

The kit **200** generally may provide the same advantages as described above with regard to the kit **100**. Additionally, the kit **200** may accommodate connections **10** of a greater range of different sizes while also minimizing the size of the connection assembly **201**. The corrugations **250**, **252** may allow the cap **230** to expand as needed to accommodate larger connections **10** and larger numbers of cables **12**, **16** so that the volume of the installed cap **230** is proportional to the size of the connection **10**. In this manner, the space required for the assembly **201** may be minimized. This may provide a particular advantage where the connection **10** is to be housed in a motor connection box where space may be limited.

The gel **210** will typically have a substantially greater coefficient of thermal expansion than the material of the cap **230**. In use, the connector assembly **201** may experience regular heat cycling as well as extreme temperature excursions. For a given rise in temperature, a portion of the gel's volumetric expansion will be expected to result in additional elongation. However, the gel **210** may also exert an outward force on the cap **230**. The corrugations **250**, **252** may flex to expand outwardly and thereby accommodate this force. The cap material may also stretch. If the temperature is subsequently lowered, the gel **210** will volumetrically contract. The flexural memory of the cap material will allow the corrugations, and thus the cap, to recover and reduce the interior volume of the cap. If the cap was also stretched by the earlier gel expansion, the elastic memory of the cap material may also allow the cap to recover. In this manner, the creation of gaps between the outer surface of the gel and

the interior surface of the cap as a result of temperature fluctuations may be minimized or prevented.

Preferably, the material of the cap **230** has a durometer and a flexural modulus as described above with regard to the cap **130**. Preferably, the corrugations **250, 252** are arranged and configured to allow for a maximum expansion of the outer diameter of the cap **230** of at least 10%, and preferably of between about 50% and 150%. It will be appreciated that corrugations of other shapes and relative configurations may be employed.

With reference to **Figures 9** and **10**, an electrical connection protector kit **300** according to further embodiments of the present invention and a protected electrical connection assembly **301** including the kit **300** mounted on the connection **10** are shown therein. The kit **300** corresponds to the kit **100** except that the cap **330** thereof is formed of a frangible material and no preformed holes corresponding to the holes **144** are provided. The frangible material is preferably a thermoplastic elastomer having a tensile strength of between about 1,000 and 3,000 psi.

The kit **300** may be installed in substantially the same manner as the kit **100**, except as follows. After the connection **10** is inserted into the gel **310** and the cap **330**, the user locates the crotch **14** of the connection **10**. The user then presses the pin **320** through the frangible cap **330**, through the crotch **14**, and then through the opposite side of the cap **330**. The pin **320** is retained in place, with the shaft **322** positioned in the connection crotch **14**, by the head **324** and the barbs **326**. In this manner, the cap **330** may be secured on the connection **10** and a compressive force may be applied to the gel **310** as discussed above with regard to the kit **100**.

While the foregoing kits preferably employ pins **120, 220, 320** as shown, the caps thereof may also be retained and compressed using other suitable means. For example, the pins may be replaced by or supplemented with a tape wrap, a clamp ring, or a clip. Also, the caps **130, 230, 330** may be formed of a heat shrinkable thermoplastic elastomer and heated after the connection **10** has been inserted. In the embodiments using pins, a series of pairs of opposed holes may be provided along the length of the cap so that the pin may be inserted through a selected pair of holes at a preferred location, depending on the location of the connection crotch **14**. The illustrated, barbed pins may be replaced with threaded pins (e.g., bolts or screws) and complementary threaded nuts.

As noted above, the gel **110, 210** is preferably cured in situ. With the cap oriented vertically with the open end up, the liquid, uncured gel may be dispensed into the cavity of the molded cap **130, 230** and thereafter cured. Preferably, thin skins of the elastomeric cap material cover the holes **144, 244** to prevent seepage of the uncured gel and also to minimize expulsion of the cured gel through the holes **144, 244** when the connection **10** is inserted during installation. Preferential tear or score lines may be provided in the skins.

With reference to **Figure 11**, a cap/pin assembly **402** according to further embodiments is shown therein. The assembly **402** includes a cap **430** generally corresponding to the cap **130** and a pin **420** generally corresponding to the pin **120**. A flexible bridge member **428** joins the pin **420** to the cap **430**. Preferably, the cap **430**, the pin **420** and the bridge member **428** are integrally molded and formed of the same material as described above with regard to the cap **130**. The assembly **402** may be used in a connection protector kit otherwise corresponding to the kit **100** or the kit **200**, for example. In use, the user may bend the bridge member **428** to insert the pin through the holes **444** of the cap **430**. In this manner, the number of loose pieces in the kit are reduced.

With reference to **Figures 12-17**, an electrical connection protector kit **500** according to further embodiments of the present invention and a protected electrical connection assembly **501** including the kit **500** mounted on the connection **10** are shown therein. The kit **500** generally corresponds to the kit **200** except that the kit **500** is secured using a clamp **560** and no pin corresponding to the pin **220** is provided. The kit **500** includes a cap **530** having outwardly extending corrugations **550** and inwardly extending corrugations or channels **552**. A gel **510** corresponding to the gel **110** is provided in the cap **530**.

The clamp **560** is preferably molded or extruded from a flexible, stretch resistant polymeric material such as polypropylene. The clamp **560** includes first and second opposed walls or legs **562, 563** which are joined along a connecting portion **564**. The widths **W** of the walls **562, 563** and the connecting portion **564** are selected to provide the desired amount of displacement of the gel **510** when the clamp is mounted and closed, as discussed in more detail below. The walls **562, 563** and the connecting portion **564** define a cavity **566**. Opposed locating projections or ribs **565** are integrally formed with and extend inwardly from the inner surfaces of the walls **562, 563** into the cavity **566**. Barbed latching structures **567, 568** are formed on the free ends of the walls

562, 563. A closure projection or rib **567A** extends outwardly from the wall **562**. Each of the locating ribs **565** and closure rib **567A** may be replaced with projections of other configurations; however, the laterally extending ribs as shown are preferred.

The nominal thickness **D** of the connecting portion **546** is preferably selected such that the walls **562, 563** may be pulled apart far enough to allow the clamp **560** to be wrapped about the cap **530**, the gel **510** and the connection **10** but the connecting portion **564** will not stretch or break under a prescribed load corresponding to the anticipated load.

The kit **500** may be used in the following manner. The connection **10** and the gel **510** are installed in the cap **530** in the same manner as described above with regard to the gel **210** and the cap **230**. The clamp **560** is opened and wrapped about the cap **530** as shown in **Figure 16** (wherein the gel and connection are omitted for clarity) such that the ribs **565** are located in opposed inwardly extending corrugations **552** and in or adjacent the crotch **14**. The clamp **560** is then compressed to close the clamp **560** about the cap **530** and to interlock the latch structures **567, 568** as shown in **Figures 12** and **17**. This action is facilitated by the rib **567A**. The rib **567A** also serves to protect the latch structures **567, 568** from unintentional disengagement.

As the clamp **560** is compressed into the closed position, the ribs **565** force the corrugations **552** inwardly into the crotch **14**, thereby deforming the cap **530** and displacing a portion of the gel **510**. The cap **530** may be deformed such that the opposed corrugations **552** fully displace the interposed gel **510** and make contact as shown in **Figure 17**, or may be displaced by a lesser amount. However, upon closure of the clamp **560**, portions of the opposed corrugations **552** are preferably disposed within the crotch **14** to prevent or resist withdrawal of the connection **10** from the cap **530**. Additionally, the ribs **565**, the walls **562, 563** and the connecting portion **564** apply a compressive force to the gel **510** as discussed above with regard to the kit **100**.

With reference to **Figures 18-20**, a clamp **660** according to further embodiments of the present invention is shown therein. The clamp **660** may be used in kits and in the same manner as described above with regard to the clamp **560**. The clamp **660** generally corresponds to the clamp **560** except that the clamp **660** includes a living hinge **669** joining the walls **662, 663** in place of the connecting portion **564**. The living hinge **669** has a substantially reduced nominal thickness **E** as compared to the nominal thicknesses **B** and **C** of the walls **662, 663**. Preferably, the living hinge **669** can be flexed through an angle of at least 180 degrees without breaking or significant plastic deformation.

With reference to **Figures 21** and **22**, an electrical connection protector kit **700** according to further embodiments of the present invention and a protected electrical connection assembly **701** including the kit **700** mounted on the connection **10** are shown therein. The kit **700** generally corresponds to the kit **500** except that the kit **700** is secured using a clamp **760** and a tie wrap **770** in place of the clamp **560**.

The clamp **760** has passages **772**, **773** extending through the walls **762** and **763** and communicating with opposed openings **772A** and **773A**. As shown, the free edges **767**, **768** are plain, but, alternatively, may be provided with latching structures corresponding to the latching structures **567**, **568**, for example. The connecting portion **764** corresponds to the connecting portion **564**, but, alternatively, may be replaced with a living hinge corresponding to the living hinge **669**.

The clamp **760** is wrapped about the cap **730** in the same manner as described above with regard to the clamp **560** such that the locating ribs **765** are received in opposed inwardly extending corrugations **752** and in or adjacent the crotch **14** (not shown in **Figure 21**). Before or after wrapping the clamp **760** about the cap **730**, a flexible strip **774** of the tie wrap **770** is inserted through the openings and passages **772**, **772A**, **773**, **773A** as shown. The lead end **774A** of the strip **774** is pulled through an opening **776A** in a lock head **776** of the tie wrap **770**. The tie wrap **770** is pulled tight to force the ribs **765** into the corrugations **752** and, in turn, the corrugations **752** into the crotch **14** as described above. The tie wrap **770** may be of conventional design, such devices being well known to those of skill in the art.

With reference to **Figures 23** and **24**, a clamp **860** according to further embodiments of the present invention is shown therein. The clamp **860** may be used in kits and in a similar manner to that described above with regard to the clamp **560**. The clamp **860** includes a first member **880** and a second member **890**. The first member **880** has a wall **882**, a locating rib **865**, and latching structures **888** and **887** on either end of the wall **882**. Similarly, the second member **890** includes a wall **892**, a locating rib **865**, and latching structures **897** and **898** on either end thereof. The first and second members **880**, **890** define a cavity **866** therebetween.

The clamp **860** may be used in the following manner. The connection **10** and gel corresponding to the gel **510** are installed in a cap corresponding to the cap **530** in the same manner as described above with regard to the kit **500**. The first and second members **880** and **890** are placed on opposite sides of the cap such that the locating ribs **865** are positioned opposite one another and adjacent the crotch **14** of the connection **10**.

The first and second members **880, 890** are then forced together by hand or using a suitable tool until the latching structures **897** and **888** and the latching structures **887** and **898** are engaged as shown in **Figures 23** and **24**.

Notably, because the caps **530, 730**, for example, employed with the clamps **560, 660, 760, 860** need not have holes to receive a pin, they may be formed without such holes. This may be beneficial during manufacture because the caps can be filled with the uncured gel material without providing means to prevent the uncured gel material from leaking through such holes.

With reference to **Figure 25**, an electrical connection protector kit **900** according to further embodiments of the present invention is shown therein. The kit **900** may be used to form a protected electrical connection assembly corresponding to the assembly **501** and including the kit **900**. For clarity, the gel and connection are omitted from **Figure 25**. The clamp **960** of the kit **900** is also shown in **Figure 26**.

The kit **900** generally corresponds to the kit **500** except that the clamp **960** includes a hole **964A** in the connecting portion **964** and the cap **930** includes an outwardly extending positioning projection **953**. The hole **964A** communicates with the cavity **966** and preferably extends fully through the thickness of the connecting portion **964**. The hole **964A** is sized to receive the positioning projection **953** therethrough.

The clamp **960** may be mounted on the cap **930**, the gel (not shown in **Figure 25**) and the connection (not shown in **Figure 25**) by placing the clamp **960** over the cap **930** such that the projection **953** is inserted through the hole **964A**. In this manner, the clamp **960** is positively axially and radially located with respect to the cap **930**. As a result, the locating ribs **965** are positively radially located such that they mate with the inwardly extending corrugations **952**. Also, in this manner, the locating projections **965** are axially located with respect to the connection in the cap **930** such that the locating projections **965** are properly positioned adjacent the crotch **14** of the connection **10**. Thereafter, the clamp **960** is secured in the manner described above with regard to the kit **500**.

The foregoing kits **500, 700, 900** and kits including the clamps **660, 860** and other kits as described herein may also be used without the gels (<u>e.g.</u>, the gels **110, 120**, etc.) to form protected electrical connection assemblies.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications

are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.